

PHYS-3301

Lecture 20

Nov. 5, 2024

Presentations

3201-501 (11/19)

Akin, Baker, Birdi, Cole, Delashaw, Ellerbrook, Garcia, Land, Matt, McKinley, O'Donnell, Sory, Torres-Rodriguez, Vasquez, Yoon

Group A (5): Birdi, Cole, Ellerbrook, O'Donnell, Yoon

Group B (5): Land, McKinley, Sory, Torres-Rodriguez, Vasquez

Group C (5): Baker, Delashaw, Garcia, Matt

3201-502 (11/26)

Aravind, Calvert, Campbell, Clapshaw, DeBreau, Higgins, Rucker, Saldivar, Simon

Group A (3): Calvert, DeBreau, Saldivar

Group B (3): Aravind, Bell, Gist, Simon

Group C (3): Clapshaw, Higgins, Rucker

Please send me the title of your presentation (20 min) **by 11/14**

e.g., Previous Presentations

Nov 28	Group	Speakers	Title
08:05 – 08:25	3201-501 Group A	Roper, Holder, Klarich	Black Holes
08:25 – 08:50	3201-501 Group B	Ormond, Veraa	Quantum Optics
08:55 – 09:15	3201-501 Group C	Schroeder, Casadei	Using Electronic density and functionals to describe multi-atom systems Part 1: Particle in a box and the wave function. Part 2: Methods on how multi atom systems are solved.
09:15 – 09:25		Martinez	Quantum Dots
Nov 30	Group	Speakers	Title
08:05 – 08:25	3201-502 Group A	McClure, Alvord, Catano	Quantum Entanglement
08:25 – 08:50	3201-502 Group B	Rana, Gist, Bell	Radiation and Radioactive Decay
08:50 – 09:15	3201-503 Group C	Stines, Lopez, Valle	Quantum Computing
09:15 – 09:25		Lascano	Photovoltaic Effect

Nov 29	Group	Speakers	Title
08:05 – 08:23	501 Group A	Singh, Prather, Sides	Wave Function Realism vs. Wave Function Instrumentalism
08:24 – 08:42	501 Group B	Hanes, Solis, Prime	The Role of Quantum Entanglement in Neuroscience
08:43 – 09:01	501 Group C	Holder, Roessler, Smith	History of the Quark
09:02 – 09:20	502 Group A	Kahrhoff, Silva, Torres, Martinez	Gravitational Waves and Gravitons
Dec 1	Group	Speakers	Title
08:05 – 08:23	502 Group B	Solodukhina, Walker, Margeta-Cacace	Data Compression of Permutations for Quantum Bits
08:24 – 08:42	502 Group C	Mahmoud, Geronimo, Musella	
08:43 – 09:01	503 Group A	Droemer, Mailman	The Zeeman Effect and how it Relates to Astrophysics
09:02 – 09:20	503 Group B	Lascano, Newman, Patton	The Effect of Quantum Tunneling on Semiconductor Technology.

Chapter. 8 Spin & Atomic Physics

Outline:

- Evidence of Angular Momentum Quantization
- Identical Particles
- The Exclusion Principle
- Multi-electron Atoms & the Periodic Table
- Characteristic X-Rays

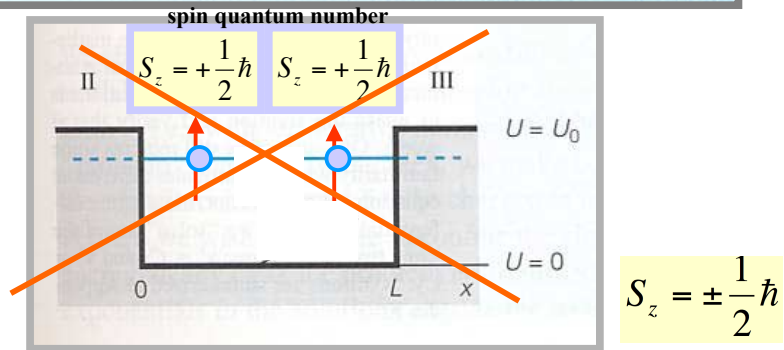
It's open said that in Q.M. there're only 3 bound-state problems solvable (w/o numerical approximation tech.)

1. Infinite well, 2. Harmonic oscillation, 3. hydrogen atom
- all 1-particle problem.

Most real application: multiple system. so, let's start an atom with multiple electrons

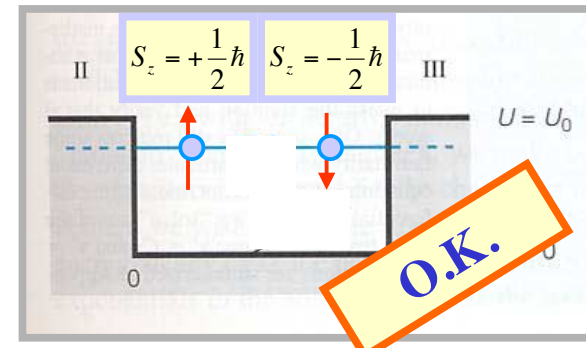
The *Pauli Exclusion Principle* for Fermions

No two indistinguishable fermions may occupy the same individual-particle state.



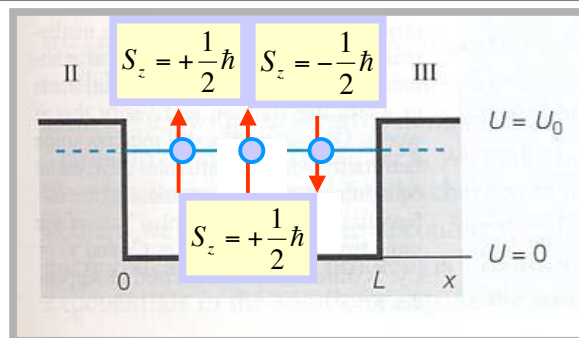
The *Exclusion Principle* for Fermions

No two indistinguishable fermions may occupy the same individual-particle state.



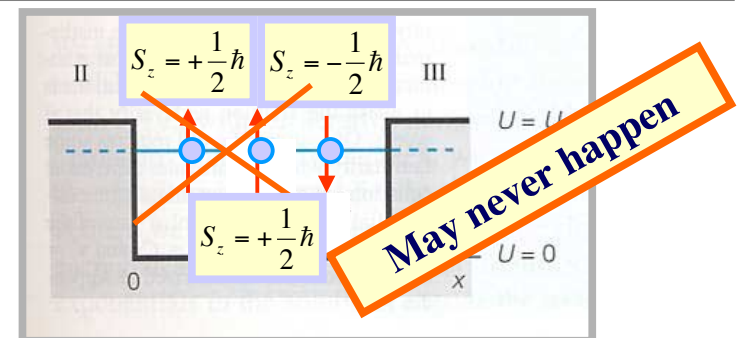
The *Exclusion Principle* for Fermions

No two indistinguishable fermions may occupy the same individual-particle state.



The *Exclusion Principle* for Fermions

No two indistinguishable fermions may occupy the same individual-particle state.



Let's "create" multi-electron atoms

Our Toolkit:

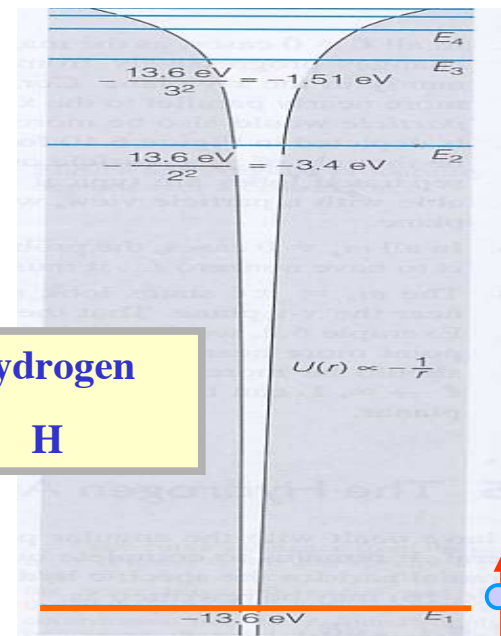
The Schrodinger Equation

The Exclusion Principle

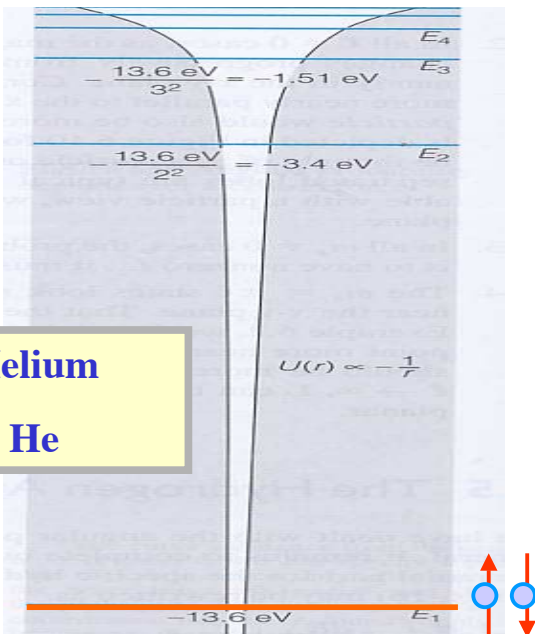
Quantization of Energy Levels

"Progressive Occupation" of Energy Levels

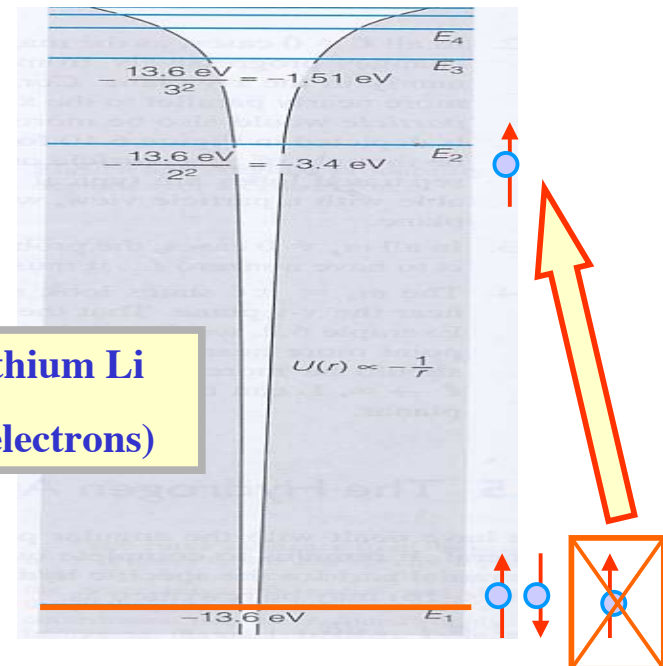
Hydrogen
H



Helium
He



Lithium Li
(3 electrons)



Energy Levels

Energy																
n	1	2				3					...	n				
ℓ	0	0	1		0	1		2			...	$0, \dots, n-1$				
m_ℓ	0	0	-1	0	+1	0	-1	0	+1	-2	-1	0	+1	+2	...	$-\ell, \dots, +\ell$
Degeneracy	1	4				9					...	n^2				

Hydrogen

H, ground state

Energy Levels

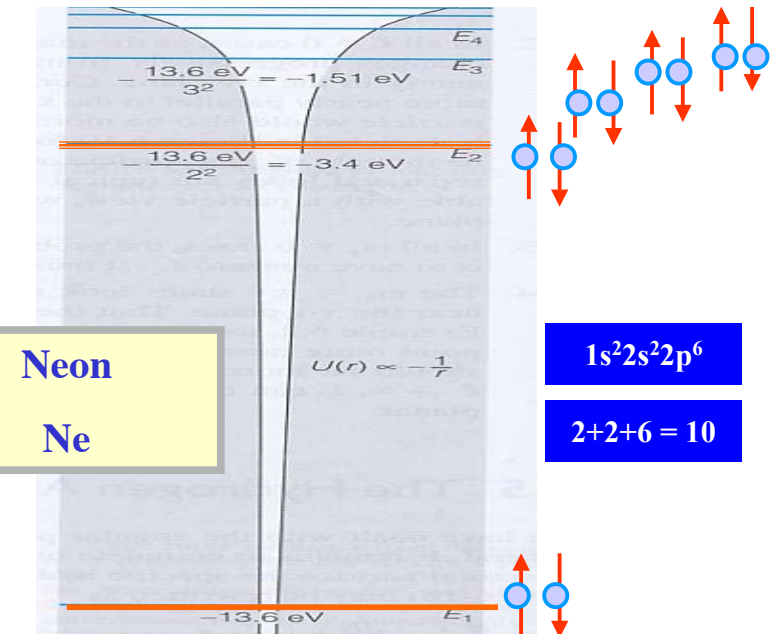
Energy																
n	1	2				3								...	n	
ℓ	0	0	1		0	1		2			...			$0, \dots, n-1$		
m_ℓ	0	0	-1	0	+1	0	-1	0	+1	-2	-1	0	+1	+2	...	$-\ell, \dots, +\ell$
Degeneracy	1	4				9								...	n^2	

He 2-electrons

Energy Levels

Energy																
n	1	2				3					...	n				
ℓ	0	0	1		0	1		2			...	$0, \dots, n-1$				
m_ℓ	0	0	-1	0	+1	0	-1	0	+1	-2	-1	0	+1	+2	...	$-\ell, \dots, +\ell$
Degeneracy	1	4				9					...	n^2				

Neon (Ne) 10-electrons



Energy Levels

Energy																
n	1	2				3					...	n				
ℓ	0	0	1		0	1		2			...	$0, \dots, n-1$				
m_ℓ	0	0	-1	0	+1	0	-1	0	+1	-2	-1	0	+1	+2	...	$-\ell, \dots, +\ell$
Degeneracy	1	9				27					...	n^2				

Fluorine: 9-electrons

$1s^2 2s^2 2p^5$

Fluorine

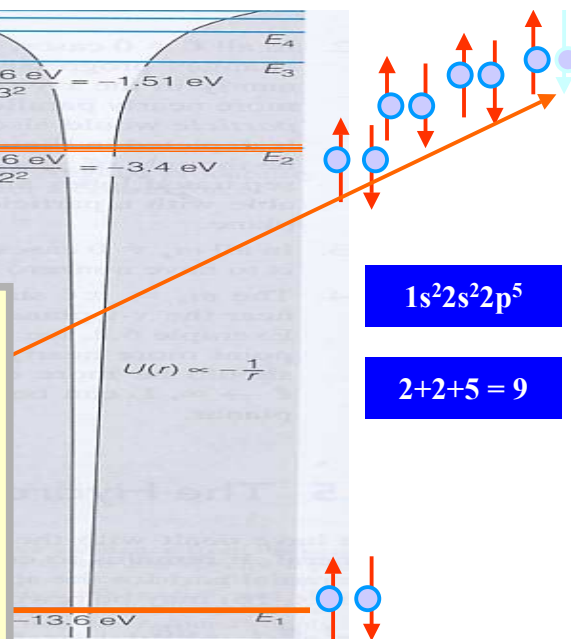
F

Like Ne with
one electron
(and proton)

less

$1s^2 2s^2 2p^5$

$2+2+5 = 9$



Fluorine

F

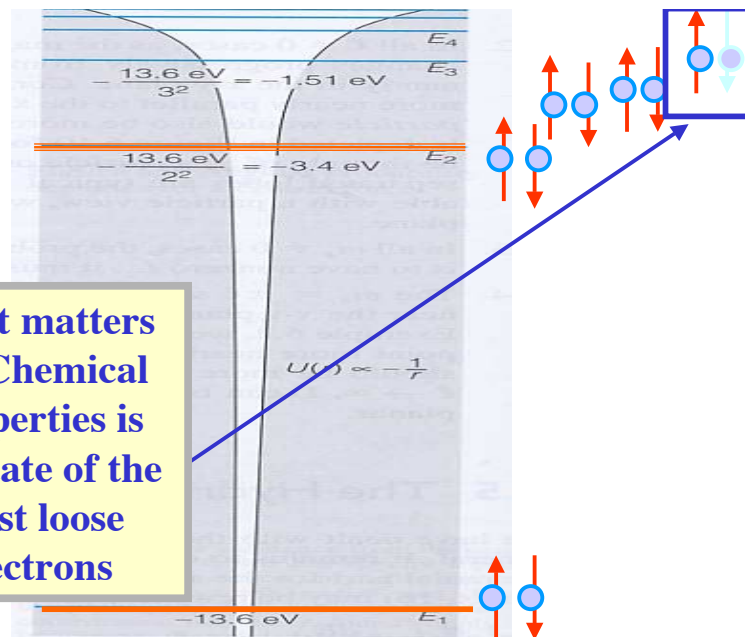
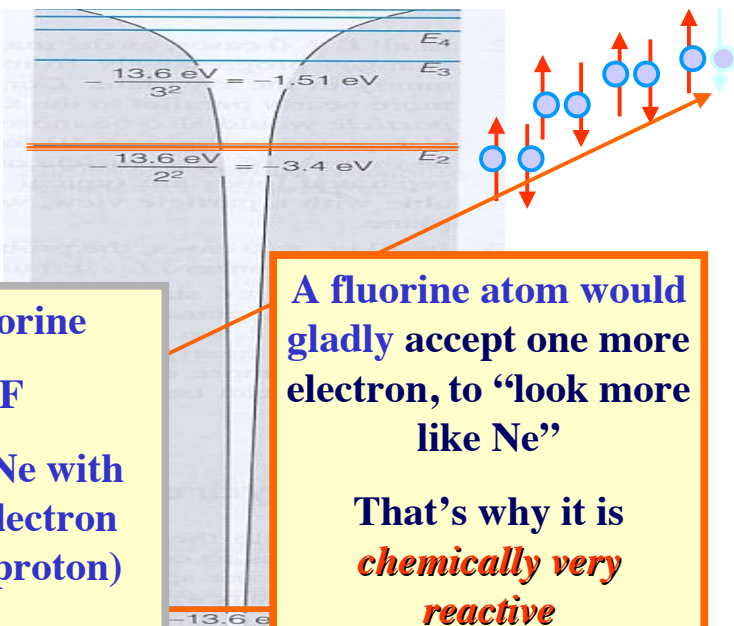
Like Ne with
one electron
(and proton)

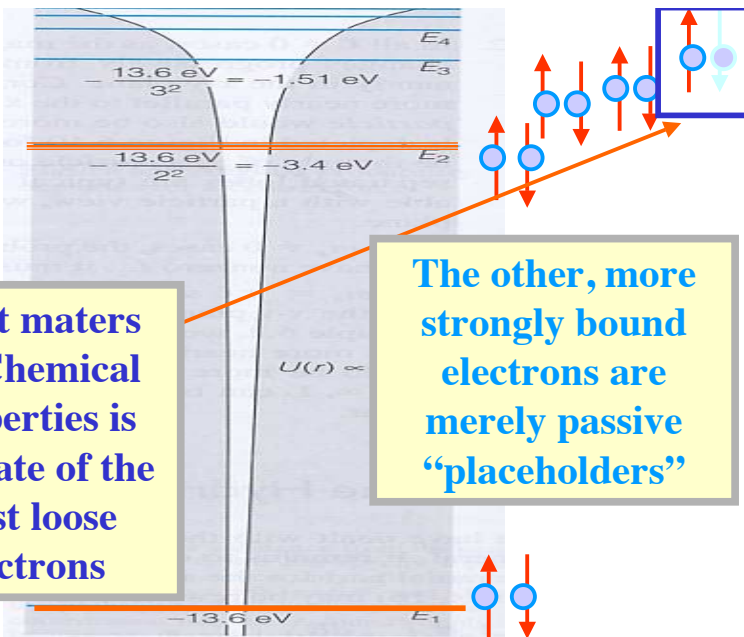
less

A fluorine atom would
gladly accept one more
electron, to “look more
like Ne”

That’s why it is
*chemically very
reactive*

What matters
for Chemical
Properties is
the state of the
most loose
electrons





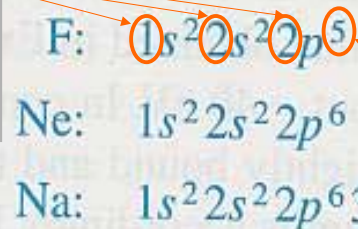
What matters for Chemical Properties is the state of the most loose electrons

The other, more strongly bound electrons are merely passive "placeholders"

The traditional naming scheme

Letter	s	p	d	f	g	h
Value of ℓ	0	1	2	3	4	5

Principal quantum number "n"



The number of electrons in that "subshell"

Symbol	He	2	Atomic number Z
	4.0026		Atomic mass*
Electronic configuration (if different from pattern)	$1s^2$		

$1s^2 2s^2 2p^5$

Subshell	ns ¹		ns ²	(n-2)f		(n-1)d ¹	(n-1)d ²	(n-1)d ³	(n-1)d ⁴	(n-1)d ⁵	(n-1)d ⁶	(n-1)d ⁷	(n-1)d ⁸	(n-1)d ⁹	np ¹	np ²	np ³	np ⁴	np ⁵	np ⁶						
Typical valence	+1		+2																	+3	+4	+5	-2	-1	0	
Shell n																										
1	H 1 1.00794																			He 2 4.0026 1.6736						
2	Li 3 6.941		Be 4 9.01218																	B 5 10.811		C 6 12.011	N 7 14.0067	O 8 15.9994	F 9 18.9984	Ne 10 20.1797
3	Na 11 22.9898		Mg 12 24.3050																	Al 13 26.9815		Si 14 28.0855	P 15 30.9738	S 16 32.066	Cl 17 35.4527	Ar 18 39.948
4	K 19 39.0983		Ca 20 40.078	Sc 21 44.9559	Ti 22 47.88	V 23 50.9415	Cr 24 51.9961	Mn 25 54.9381	Fe 26 55.847	Co 27 58.9332	Ni 28 58.6934	Cu 29 63.546	Zn 30 65.39	Ga 31 69.723	Ge 32 72.61	As 33 74.9216	Se 34 78.96	Br 35 79.904	Kr 36 83.80							
5	Rb 37 85.4678		Sr 38 87.62	Y 39 88.9059	Zr 40 91.224	Nb 41 92.9064	Mo 42 95.94	Tc 43 (98)	Ru 44 101.07	Rh 45 102.906	Pd 46 106.42	Ag 47 107.868	Cd 48 112.411	In 49 114.82	Sn 50 118.710	Sb 51 121.757	Te 52 127.60	I 53 126.904	Xe 54 131.29							
6	Cs 55 132.905		Ba 56 137.327	La 57 138.905	Hf 72 178.49	Ta 73 180.948	W 74 183.85	Re 75 186.207	Os 76 190.2	Ir 77 192.22	Pt 78 195.08	Au 79 196.967	Hg 80 200.59	Tl 81 204.383	Pb 82 207.2	Bi 83 208.980	Po 84 (209)	At 85 (210)	Rn 86 (222)							
7	Fr 87 (223)		Ra 88 (226)	Ac 89 227	Th 90 232	Pa 91 231	U 92 238	Np 93 237	Pu 94 244	Am 95 243	Cm 96 247	Bk 97 247	Cf 98 251	Es 99 252	Fm 100 257	Md 101 258	No 102 259	Lr 103 260								

	f ¹	f ²	f ³	f ⁴	f ⁵	f ⁶	f ⁷	f ⁸	f ⁹	f ¹⁰	f ¹¹	f ¹²	f ¹³	f ¹⁴
Lanthanides	La 57 138.905 5d ¹ 6s ²	Ce 58 140.115 4f ¹ 5d ¹ 6s ²	Pr 59 140.908 4f ² 6s ²	Nd 60 144.24 (145)	Pm 61 (145)	Sm 62 150.38	Eu 63 151.965	Gd 64 157.25 4f ⁷ 5d ¹ 6s ²	Tb 65 158.925 4f ⁹ 6s ²	Dy 66 162.50	Ho 67 164.930	Er 68 167.26	Tm 69 168.934	Yb 70 173.04
Actinides	Ac 89 (227) 6d ¹ 7s ²	Th 90 232.0377 6d ² 7s ²	Pa 91 231.03688 5f ¹ 6d ¹ 7s ²	U 92 238.02891 5f ³ 6d ¹ 7s ²	Np 93 237.04817 5f ⁴ 6d ¹ 7s ²	Pu 94 244.06422 5f ⁶ 7s ²	Am 95 243.06138 5f ⁷	Cm 96 247 5f ⁷ 6d ¹ 7s ²	Bk 97 247 (251)	Cf 98 251 (251)	Es 99 252 (252)	Fm 100 257 (257)	Md 101 258 (258)	No 102 259 (259)

Noble gasses

Subshell → Typical valence →	ns ¹	ns ²	(n-2)f	(n-1)d ¹	(n-1)d ²	(n-1)d ³	(n-1)d ⁴	(n-1)d ⁵	(n-1)d ⁶	(n-1)d ⁷	(n-1)d ⁸	(n-1)d ⁹	(n-1)d ¹⁰	np ¹	np ²	np ³	np ⁴	np ⁵	np ⁶
	+1	+2												+3	+4	+5	-2	-1	0
Shell n																			
1	H 1 1.00794																		He 2 4.0026 1s ¹
2	Li 3 6.941	Be 4 9.01218																	
3	Na 11 22.9898	Mg 12 24.3050																	
4	K 19 39.0983	Ca 20 40.078																	
5	Rb 37 85.4678	Sr 38 87.62																	
6	Cs 55 132.905	Ba 56 137.327	La-70																
7	Fr 87 (223)	Ra 88 (226)	Ac-100																

	f ¹	f ²	f ³	f ⁴	f ⁵	f ⁶	f ⁷	f ⁸	f ⁹	f ¹⁰	f ¹¹	f ¹²	f ¹³	f ¹⁴
Lanthanides	La 57 138.905 5d ¹ 6s ²	Ce 58 140.115 4f ¹ 5d ¹ 6s ²	Pr 59 140.908 4f ² 6s ²	Nd 60 144.24 (145)	Pm 61 (145)	Sm 62 150.38 151.965	Eu 63 157.25 158.925 4f ⁷ 5d ¹ 6s ²	Gd 64 157.25 158.925 4f ⁷ 5d ¹ 6s ²	Tb 65 162.50 160.50	Dy 66 162.50 164.930	Ho 67 164.930	Er 68 167.26 168.934	Tm 69 168.934	Yb 70 173.04
Actinides	Ac 89 (227) 6d ¹ 7s ²	Th 90 232.038 (231)	Pa 91 231.036 5f ¹ 6d ¹ 7s ²	U 92 238.029 (237)	Np 93 (237)	Pu 94 (244)	Am 95 (243)	Cm 96 (247)	Bk 97 (247)	Cf 98 (251)	Es 99 (252)	Fm 100 (257)	Md 101 (258)	No 102 (259)

Noble gasses

Subshell → Typical valence →	ns^1	ns^2	$(n-2)f$	$(n-1)d^1$	$(n-1)d^2$	$(n-1)d^3$	$(n-1)d^4$	$(n-1)d^5$	$(n-1)d^6$	$(n-1)d^7$	$(n-1)d^8$	$(n-1)d^9$	$(n-1)d^{10}$	np^1	np^2	np^3	np^4	np^5	np^6
Shell n	+1	+2												+3	+4	+5	-2	-1	0
1	H 1 1.00794																		He 2 4.0026 $1s^2$
2	Li 3 6.941	Be 4 9.01218																	
3	Na 11 22.989	Mg 12																	
4	K 19 39.098	Ca 20																	
5	Rb 37 85.4678	Sr 38																	
6	Cs 55 132.905	Ba 56																	
7	Fr 87 (223)	Ra 88 (226)																	

He + 1 electron

Li: $1s^2 2s^1$

	f^1	f^2	f^3	f^4	f^5	f^6	f^7	f^8	f^9	f^{10}	f^{11}	f^{12}	f^{13}	f^{14}
Lanthanides	La 57 138.905 $5d^1 6s^2$	Ce 58 140.115 $4f^1 5d^1 6s^2$	Pr 59 140.908 $4f^2 6s^2$	Nd 60 144.24 (145)	Pm 61 (145)	Sm 62 150.38	Eu 63 151.965	Gd 64 157.25 $4f^7 5d^1 6s^2$	Tb 65 158.925 $4f^8 6s^2$	Dy 66 162.50	Ho 67 164.930	Er 68 167.26	Tm 69 168.934	Yb 70 173.04
Actinides	Ac 89 (227) $6d^1 7s^2$	Th 90 232.038 $6d^2 7s^2$	Pa 91 231 $5f^2 6d^1 7s^2$	U 92 238.029 $5f^3 6d^1 7s^2$	Np 93 237 $5f^4 6d^1 7s^2$	Pu 94 244 $5f^6 7s^2$	Am 95 243 $5f^7 7s^2$	Cm 96 247 $5f^7 6d^1 7s^2$	Bk 97 247 $5f^9 7s^2$	Cf 98 (251)	Es 99 (252)	Fm 100 (257)	Md 101 258 $5f^7 7s^2$	No 102 (259)

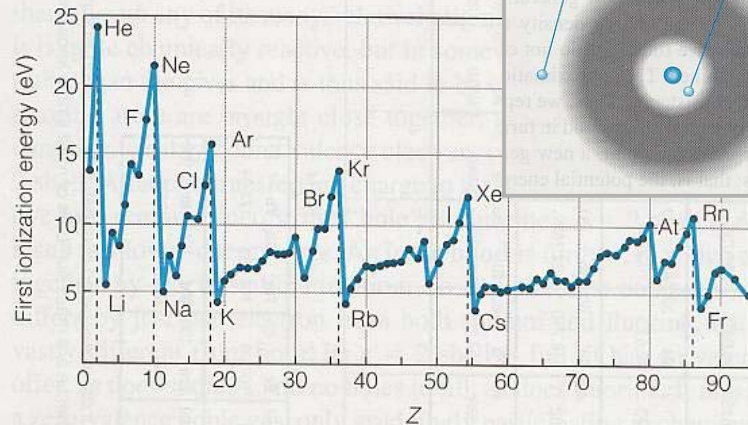
Symbol	He	2	Atomic number Z
	4.0026		Atomic mass*
Electronic configuration (if different from pattern)	$1s^2$		

Subshell → Typical valence →	ns^1	ns^2	$(n-2)f$	$(n-1)d^1$	$(n-1)d^2$	$(n-1)d^3$	$(n-1)d^4$	$(n-1)d^5$	$(n-1)d^6$	$(n-1)d^7$	$(n-1)d^8$	$(n-1)d^9$	$(n-1)d^{10}$	np^1	np^2	np^3	np^4	np^5	np^6
Shell n	+1	+2												+3	+4	+5	-2	-1	0
1	H 1 1.00794																		He 2 4.0026 $1s^2$
2	Li 3 6.941	Be 4 9.01218																	
3	Na 11 22.989	Mg 12																	
4	K 19 39.098	Ca 20																	
5	Rb 37 85.4678	Sr 38																	
6	Cs 55 132.905	Ba 56																	
7	Fr 87 (223)	Ra 88 (226)																	

VALENCE

	f^1	f^2	f^3	f^4	f^5	f^6	f^7	f^8	f^9	f^{10}	f^{11}	f^{12}	f^{13}	f^{14}
Lanthanides	La 57 138.905 $5d^1 6s^2$	Ce 58 140.115 $4f^1 5d^1 6s^2$	Pr 59 140.908 $4f^2 6s^2$	Nd 60 144.24 (145)	Pm 61 (145)	Sm 62 150.38	Eu 63 151.965	Gd 64 157.25 $4f^7 5d^1 6s^2$	Tb 65 158.925 $4f^8 6s^2$	Dy 66 162.50	Ho 67 164.930	Er 68 167.26	Tm 69 168.934	Yb 70 173.04
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First Ionization Energy



Symbol	He	2	Atomic number Z
	4.0026		Atomic mass*
Electronic configuration (if different from pattern)	$1s^2$		

Subshell → Typical valence →	ns^1	ns^2	$(n-2)f$	$(n-1)d^1$	$(n-1)d^2$	$(n-1)d^3$	$(n-1)d^4$	$(n-1)d^5$	$(n-1)d^6$	$(n-1)d^7$	$(n-1)d^8$	$(n-1)d^9$	$(n-1)d^{10}$	np^1	np^2	np^3	np^4	np^5	np^6
Shell n	+1	+2												+3	+4	+5	-2	-1	0
1	H 1 1.00794																		He 2 4.0026 $1s^2$
2	Li 3 6.941	Be 4 9.01218																	
3	Na 11 22.989	Mg 12																	
4	K 19 39.098	Ca 20																	
5	Rb 37 85.4678	Sr 38																	
6	Cs 55 132.905	Ba 56																	
7	Fr 87 (223)	Ra 88 (226)																	

“Alkali metals”

	f^1	f^2	f^3	f^4	f^5	f^6	f^7	f^8	f^9	f^{10}	f^{11}	f^{12}	f^{13}	f^{14}
Lanthanides	La 57 138.905 $5d^1 6s^2$	Ce 58 140.115 $4f^1 5d^1 6s^2$	Pr 59 140.908 $4f^2 6s^2$	Nd 60 144.24 (145)	Pm 61 (145)	Sm 62 150.38	Eu 63 151.965	Gd 64 157.25 $4f^7 5d^1 6s^2$	Tb 65 158.925 $4f^8 6s^2$	Dy 66 162.50	Ho 67 164.930	Er 68 167.26	Tm 69 168.934	Yb 70 173.04
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Chapter. 9

Statistical Mechanics

Statistical mechanics is NOT non-classical or modern physics in the same sense that special relativity and QM are. Rather, it's a distinct area of physics that applies to many others; either classical or QM.

Q.: Why study it now? A.: many modern physics require it.

e.g. A gas laser: thermodynamics system of gas molecules

A semiconductor: thermodynamics system of atom bound in a solid lattice

**** Thermodynamic system = countless particles; precise average behavior.**

Chapter. 9

Statistical Mechanics

Outline:

- Historical Overview
- The Boltzmann Distribution
- Maxwell Velocity Distribution
- Equipartition Theorem
- Maxwell Speed Distribution
- Classical and Quantum Statistics
- Fermi-Dirac Statistics
- Bose-Einstein Statistics

9.1: Historical Overview

Statistics and probability

- New mathematical methods developed to understand the Newtonian physics through the 18th and 19th centuries.

Lagrange around 1790 and **Hamilton** around 1840.

- They added significantly to the computational power of Newtonian mechanics.

Pierre-Simon de Laplace (1749-1827)

- Made major contributions to the theory of probability

Historical Overview

Benjamin Thompson (Count Rumford)

- Put forward the idea of heat as merely the motion of individual particles in a substance

James Prescott Joule

- Demonstrated the mechanical equivalent of heat

James Clark Maxwell

- Brought the mathematical theories of probability and statistics to bear on the physical thermodynamics problems
- Showed that distributions of an ideal gas can be used to derive the observed macroscopic phenomena
- His electromagnetic theory succeeded to the statistical view of thermodynamics

Historical Overview

Einstein

- Published a theory of Brownian motion, a theory that supported the view that atoms are real

Bohr

- Developed atomic and quantum theory
-